

Sustained Supersonic Propagation of Efficient Ionization Waves Generated by Laser-Irradiated Underdense Foams

Large area x-ray sources are necessary for radiographing extended targets. One method for creating efficient and spatially uniform x-ray sources being tested uses low-density target materials such as confined gases or foams exposed to high-power laser irradiance. The absorption front of the incident laser energy advances inside the target at supersonic velocities, hence mitigating hydrodynamic losses. Previous work had demonstrated the concept in confined gases; in this case we

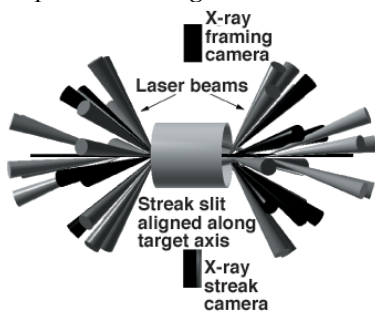


Figure 1. Target geometry and laser beams configuration.

Janus Experiments Observe Nonlocal Heat Wave in Laser Plasma

The propagation of heat away from laser-irradiated plasma spots that is crucial to understanding and optimizing laser-driven ICF has been a topic of continual theoretical work but little conclusive experimental verification for three decades. A new absolutely calibrated imaging Thomson scattering technique has now been applied for the first accurate measurements of the radially expanding heat wave profile from a laser-heated nitrogen gas jet plasma produced at the Janus facility. A 250-eV, 0.16-mm initial radius cylindrical plasma is formed by a 1- μm wavelength, 0.8-ns duration, 10^{14} W/cm² beam and probed as a function of time by a noninvasive orthogonal 0.53- μm wavelength, 130-ps beam. Figure 1 shows

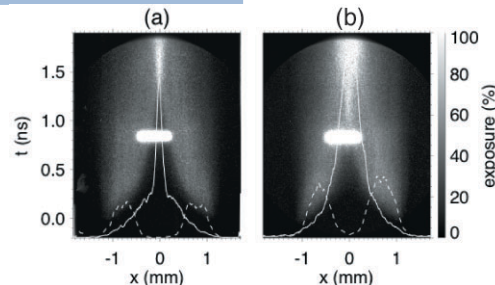


Figure 2. Streaked >4-keV x-ray images of the heat waves propagation during and after the laser pulse, recorded in conditions of laser incident intensity of: (a) 1.7×10^{15} W/cm² and (b) 3.4×10^{15} W/cm².

employed very low density (3 mg/cm³) silica aerogel targets doped with 3 at.% Ti, which when fully ionized reaches 9% of the laser critical density. The fragile doped foams were enclosed in 2-mm-sized Be cylinders whose walls are transparent to multi-keV x-rays. The targets were irradiated on the OMEGA laser facility using 1-ns laser pulses, with energies ranging from 180 to 380 J, giving an average total power from 3.6 to 7.6 TW onto each laser entrance hole (LEH) of the cylinder (Fig. 1). A Bragg-crystal spectrometer measured the Ti K-shell spectra, from which plasma temperatures between 2 and 2.25 keV were inferred. These values compare well with the predicted 1.7- to 3-keV plasma temperatures computed theoretically by LASNEX code.

The heat wave propagation from the LEH to the center of the target was time- and space-resolved using an imaging x-ray streak camera, which recorded the position of the Ti x-ray front over a time window of 2 ns. Measurements of the wavefront position shown in Fig. 2 for two irradiances demonstrated supersonic propagation for at least 1 ns with a maximum initial speed of 5.5 mm/ns, representing an initial Mach No. of almost 20. These were the first observations of sustained supersonic propagation of a laser-driven heat wave in underdense foam targets. They demonstrate the possibility of efficient heating of large samples of underdense foam targets over ns durations.

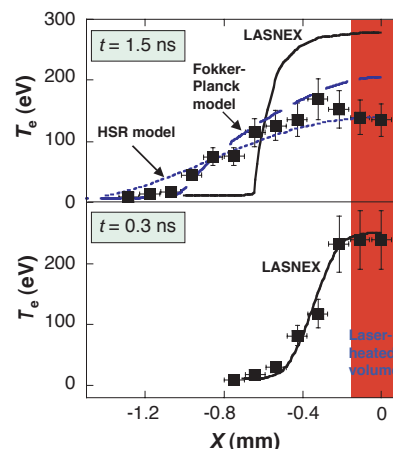


Figure 1. Comparison of electron temperature profile data at two times inferred from Thomson scattering and various theoretical calculations showing good agreement late in time with the nonlocal models in blue.

the inferred electron temperature profile at two times from the spectrally resolved Thomson-scattered probe light, spatially resolved along the outward radial

direction from the initial plasma column. In the first 0.3 ns, the heating is described well by a local heat-flux limiting model, which is employed by the hydrodynamics code LASNEX. However, when the heater beam turns off, the heat wave has extended further out into the gas than predicted by the local model. In particular, the gas has already been heated to ≈ 50 eV after 1.5 ns at a radius of 1 mm, six times the initial plasma column radius. Nonlocal simulations with two models (hot spot relaxation [HSR] and Fokker-Planck) are required to explain the large extent of the heat wave and the shape of the temperature profile. These heat transport models take into account the fast (non-Maxwellian) electrons generated in the laser spot that have a small collision frequency and can consequently carry heat over long distances (hence the term nonlocal).